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OPERATIONAL CONTROL PROCEDURES FOR THE ACTIVATED SLUDGE PROCESS. PART II. CONTROL TESTS

Alfred W. West

National Field Investigations Center
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NATIONAL FIELD INVESTIGATIONS CENTER - CINCINNATI

OPERATIONAL CONTROL PROCEDURES
FOR THE
ACTIVATED SLUDGE PROCESS
PART II
CONTROL TESTS

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by

Alfred W. West, P. E.
Chief, Waste Treatment Branch

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF ENFORCEMENT AND GENERAL COUNSEL

I

FOREWORD

The Waste Treatment Branch of the National Field Investigations Center - Cincinnati is developing a series of pamphlets describing Operational Control Procedures for the Activated Sludge Process. This series will include Part I Observations, Part II Control Tests, Part III Calculation Procedures, Part IV Sludge Quality, Part V Process Control and an Appendix. Each one of these individual parts will be released for distribution as soon as it is completed. The original five-part series may then be expanded to include special case histories and refined process evaluation and control techniques.

This pamphlet has been developed as a reference for Activated Sludge Plant Control lectures I have presented at training sessions, symposia, and workshops. It is based on my personal conclusions reached while directing the operation of dozens of different activated sludge plants. This pamphlet is not necessarily an expression of Environmental Protection Agency policy or requirements.

The mention of trade names or commercial products in this pamphlet is for illustrative purposes and does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

A. W. West

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OBJECTIVES

Control tests, that can be run as frequently as needed throughout each 24-hour cycle, reveal sludge quality, process status, and final effluent quality.

Results of the settlometer, centrifuge and final clarifier sludge blanket level tests are used to calculate solids distribution ratios between the aeration tanks and the final clarifiers, sludge detention time in the final clarifiers and other factors influencing process performance.

The coordinated results of the full test series, including flow records, turbidity, and dissolved oxygen test data, are ultimately used to determine the return sludge flow, excess sludge wasting and air discharge rates needed to maintain or restore excellent final effluent quality.

INTRODUCTION

Practically all information needed to define sludge quality and process status and to calculate control adjustment requirements can be determined from the results of a few relatively simple tests. The entire series of settlometer, centrifuge, sludge blanket depth, effluent turbidity and dissolved oxygen tests can be completed in about ninety minutes and can, therefore, be run as frequently as needed throughout each 24-hour cycle.

The complete test series should be run at least once every eight-hour operating shift. The sludge blanket and the fifteen minute centrifuge tests should be run more frequently whenever rapidly changing process characteristics demand more critical scrutiny and control. Though simple, informative, and too frequently neglected, these tests are neither new or difficult. They were, in fact, proposed by E. B. Mallory more than thirty years ago. Though the testing techniques and some of the data processing methodology includes that proposed by Mallory, the procedures and calculations for determining control adjustment requirements, as discussed in these pamphlets, were developed by me.

These discussions include only those control tests that are used directly to identify process performance and to dictate process control adjustments. Other important monitoring type tests, such as BOD, COD, etc., are not included in these discussions.

METER READING

Each control test series should be started by reading plant meters to record flow data that are needed to determine process requirements.

Flow records specifically related to control of the activated sludge process include:

Aeration Tanks

Total influent sewage flow to aeration tanks

Return sludge flow to aeration tanks

Total air to aeration tanks

Final Clarifiers

Mixed liquor flow to clarifiers

Sludge removed from clarifiers

Excess Sludge to Waste

Mixed liquor wasted

Return sludge wasted

The extent of additional flow data needed to evaluate and control total plant performance will vary from plant to plant. Other waste streams that should also be measured could include:

Raw sewage flow

Plant drainage recycled to primaries

Primary sludge flow

Sludge thickener flows

Sludge filtrate flows

Digester supernatant flow

Sludge removed from plant

Plant drainage recycled to aeration tanks

Final effluent reuse

Final effluent flow

The following discussion is limited specifically to the activated sludge portion of the treatment plant. For multiple tank plants, having three aeration tanks and three final clarifiers, for example, the operator should also routinely maintain equal hydraulic loading to each of the parallel operating units.

The following flow rates should be determined during each test period and the 24-hour totalized value of each should be recorded every day.

SEWAGE FLOW INTO EACH AERATION TANK

Frequently overall treatment is impeded when aeration tank loadings cannot, or are not, balanced properly between the parallel aeration tanks. The better treatment provided by an underloaded tank unit will not compensate fully for the poorer treatment provided by the overloaded unit.

RETURN SLUDGE FLOW INTO EACH AERATION TANK

Maldistribution of return sludge flow, especially when coupled with unequal sewage flow loading between parallel aeration tanks, can further distort the proportionate purification pressures (mixed liquor concentration and detention times) and reduce treatment capability.

AIR DISCHARGE TO EACH AERATION TANK

Here, again, unequal distribution as well as inadequate excessive total air flow can degrade sludge quality and purification.

The basic indicating, recording, and totalizing meters should be used to measure and control air flow to each aeration tank. Simple indicating meters should be observed to assure proper air distribution to the main air headers feeding each bay or compartment of individual aeration tanks.

MIXED LIQUOR FLOW INTO EACH FINAL CLARIFIER

The influent flow to each clarifier should be determined during each test period so that the surface overflow rates and the solids loadings can be distributed properly to each clarifier. This is especially important during troublesome times when rising sludge blankets warn that classic sludge bulking may be imminent.

If the clarifier flows are not balanced properly at such times, mixed liquor sludge can be forced out over the final weirs of the overloaded clarifier, while the sludge blankets in the other clarifiers may remain low enough to produce a clear effluent. Unfortunately, this may occur when proper flow distribution could otherwise have held the sludge blankets safely below the water surface of all clarifiers.

SLUDGE REMOVED FROM EACH CLARIFIER

These meters, one for each tank, should also be read at each test period and the totalized value should be recorded each day. Here again, the need to balance sludge removal from all clarifiers to maintain proper sludge blanket level control is obvious.

EXCESS SLUDGE FLOW TO WASTE

This meter, or meters, should be read at every test period and whenever the wasting rate is changed.

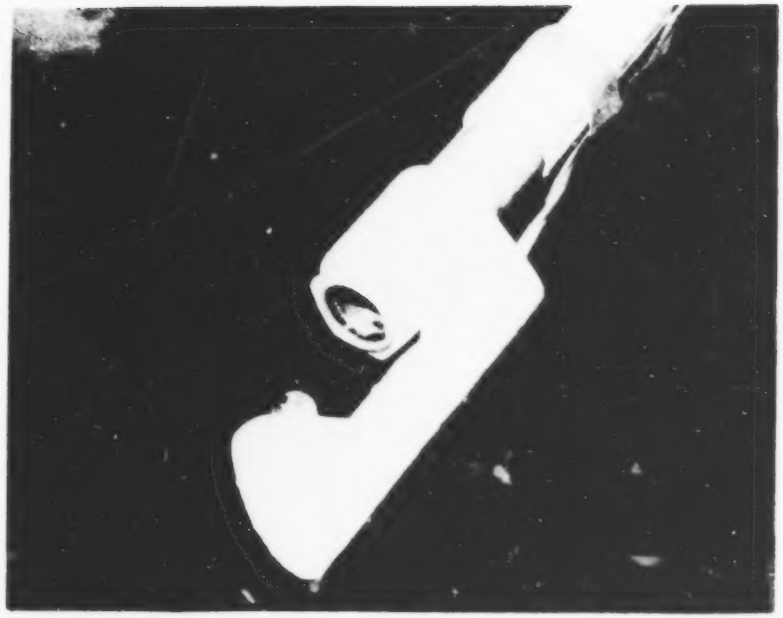
Procedures to use flow data and other control test results to determine return sludge, waste sludge, and other process requirements will be discussed in other parts of this pamphlet series.

DEPTH OF SLUDGE BLANKET

After checking the meters, an operator following a logical test schedule should move on to determine final clarifier characteristics. He should determine the depth of the sludge blanket that has accumulated within the clarifier and observe conditions at and near the water surface.

Various types of sludge blanket depth finders are used. The type described in the next paragraph can be constructed simply and used conveniently; and when handled properly, it becomes a valuable, reliable operational control tool. At least two sludge blanket finders should be provided to assure continuity of test results, especially when one is being repaired. One should be long enough to reach from the bridge to the tank bottom. The other shorter one should only be long enough to extend about half way down into the tank.

An optical sludge depth blanket finder can be made from a graduated piece of aluminum pipe railing with an illuminated



SLUDGE BLANKET FINDER
LIGHT AND SIGHT GLASS

OPERATOR STARTING
DEPTH OF BLANKET TEST

watertight sight glass on the bottom end. A flashlight bulb, bracketed below the sight glass, is wired to a switched battery located near the top of the blanket finder. The blanket finder should be constructed of a single, continuous length of pipe; since pipe joints can leak, dirty up the sight glass, permit undue deflection of the pipe, and ultimately make the finder inoperative.

Other types of blanket finders include wands with photo-electric cell buzzer actuators and a series of small airlift pumps extending down to different measured depths within the final clarifier. The operator should use the type he finds most convenient, but it is suggested that the reliable pipe and sight glass type described previously be provided, at least as a back-up instrument.

It takes a little practice for an operator to use a blanket finder, or, more exactly, to know what he is looking for, but after a few diligent attempts he will be surprised at how accurately and easily blanket depths can be determined.

A cross section of most clarifiers containing a reasonably good sludge solids distribution balance may reveal a zone of discrete straggler floc particles settling down to form the blanket. Somewhat farther than half-way down into the tank,

there will usually be a distinct plane of demarcation between the individual settling sludge particles and the relatively thin, but quite homogeneous, upper surface of the accumulated sludge blanket. Then the concentration of this sludge blanket will usually increase in density down to the zone of maximum compaction at the very bottom of the tank.

Here are two precautions - which will only be resolved by practice. Do not stop the downward movement of the blanket finder when the individual discrete sludge particles are observed. Secondly, do not force the blanket finder down to the point where the denser sludge within the blanket actually obscures the light. Instead, move the blanket finder down at a rather rapid uniform rate through the clear liquor, then continue down through the zone containing individual floc particles, and finally stop when the upper surface of the definite homogeneous sludge mass is observed. Take your reading at this point; you have reached the upper surface of the sludge blanket.

The blanket reading station should be located at a point where the single measurement will approximate the average depth of the entire sludge blanket. A station on the final clarifier bridge, about one-third of the tank radius in from the outer tank wall, will usually satisfy this requirement. The selected station should be marked so that blanket depths are always measured at the same location.

SAMPLE COLLECTION

Samples for the control tests and other laboratory work must be collected on time, from appropriate locations, according to approved procedures; and they certainly must be representative. These elementary principles can not be violated without cost.

CENTRIFUGE TEST SAMPLES

After observing the aerators and clarifiers, return sludge samples should be collected for the centrifuge test. Selection of the sampling station for collecting samples that truly represent the actual quality of the entire return and waste sludge flow is most important. It is best to collect the sample from the point where the thoroughly mixed return sludge from all clarifiers enters the aeration tanks. If such location is inaccessible, the sample should be taken from a tap off the return sludge pump discharge header. The sample pipe should obviously be flushed out thoroughly before each sample is collected. Since mixing may be inadequate, sampling from deep wet wells should be avoided if at all possible.

In addition to the sample collected for basic plant control, individual return sludge samples should be collected from each final clarifier to check or to balance multi-tank performance.

Then at times, samples should be collected from each of the individual sludge draw-off tubes in each final clarifier. This series of samples need be collected only as frequently as required to assure uniform sludge withdrawal from the entire clarifier floor area. Ordinarily, such "trim spin" samples are collected about once each week.

The samples collected for the settlometer test, as described in a following section, will also be used to determine the centrifuged concentration of the mixed liquor solids.

TURBIDITY TEST SAMPLES

Special samples should also be collected from the final clarifier to determine the turbidity of the treated waste. These samples for turbidity should be collected deliberately from the clearest area of the final clarifier water surface that contains the least surface sludge or scum that may be present. When collected in this manner, these samples will indicate specific process performance, undistorted by clarifier or other equipment defects that may need correction. Other 24-hour composite samples collected for plant monitoring (BOD, COD, TSS, etc.) will be used to determine net process performance.

SETTLOMETER TEST SAMPLES

The mixed liquor sample for the settlometer test should be collected last of all. This sample, which should represent the average quality of all mixed liquor flowing out of all aeration

tanks, will also be used to determine solids concentration both by centrifuge and by weight. Preferably, this sample should be collected from the common discharge flume that contains all mixed liquor flowing from the outlet of all active aeration tanks. If the common discharge header is inaccessible, equal volumes of mixed liquor should be collected from the outlet end of each aeration tank and composited into a single representative sample for the settleability and solids concentration tests.

The necessity for collecting mixed liquor samples in wide-mouthed containers, rushing the samples to the laboratory, and starting the settlometer test immediately, can not be over emphasized. After collection, the samples should be subjected to the absolute minimum amount of agitation and aeration. Improper sample handling, such as violent shaking or splashing, or unwarranted delay between the time that the sample is collected and the time it is poured into the settlometer, can alter sludge settling characteristics and induce erroneous settlometer test results.

SETTLOMETER TESTS

Preferably, mixed liquor sludge settleability tests should be determined in a clear glass cylinder with a larger diameter and a lesser depth than the standard 1,000 cc graduated cylinder

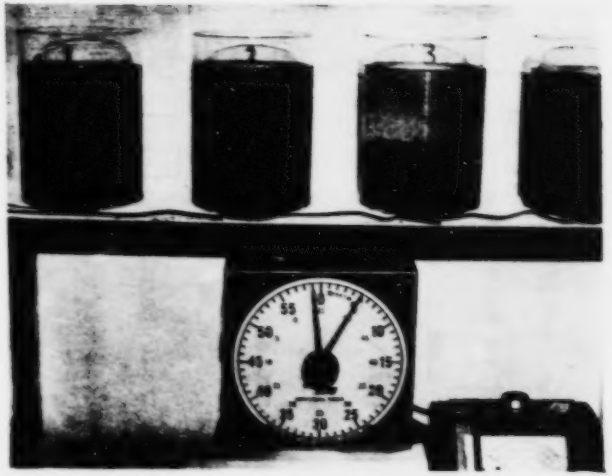
that is frequently used for this test. A glass cylinder shaped similar to the standard two-liter beaker, but with better graduations and without the rounded bottom edge, would be satisfactory. Many operators now prefer the five inch diameter, six inch depth, two-liter Mallory settlometer that is graduated in tenths and hundredths of the settlometer volume.

The mixed liquor sludge should be poured into the settlometer carefully and rapidly and with the least possible amount of additional aeration or disturbance. The settlometer contents should be stirred gently to assure thorough mixing; and then all swirling should be dampened immediately with a wide paddle before the timer is started.

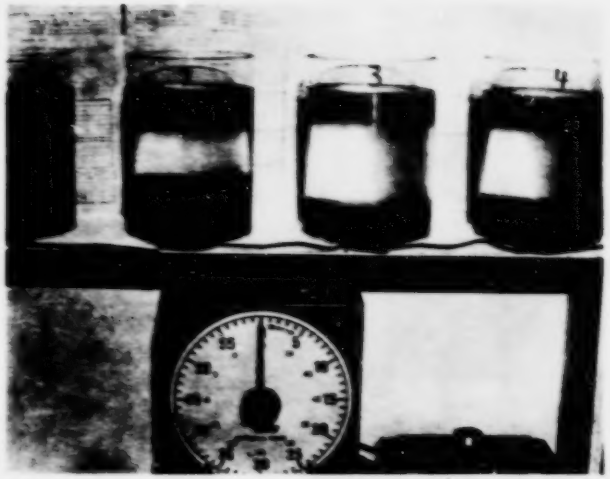
The volume of the settlometer occupied by settled sludge should be read and recorded at every five-minute interval for the first thirty minutes and at every ten-minute interval for the second thirty minutes of the one hour settlometer test.

Operators who set up a test cylinder, walk away, and then return for a single observation after thirty minutes, miss most of the information that actually defines sludge quality. A single thirty-minute test, to determine SVI, is somewhat like a five-day BOD, and, as you know, the five-day BOD reveals only one

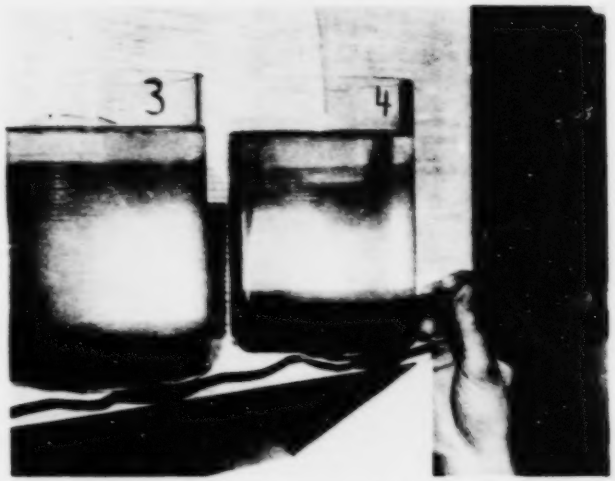
TEST SET-UP



5 MINUTE READING



1 HOUR APPEARANCE



1 HOUR READING

SETTLOMETER TEST

point in a progressive reaction and it will not help an evaluator who is really interested in reaction rates and the full impact of ultimate demands.

The first five-minute reading is one of the two most important observations for this test. During this first five minutes the conscientious operator will critically observe how the sludge particles agglomerate while forming the blanket. He will see whether the sludge compacts slowly and uniformly while squeezing clear liquid from the sludge mass or whether tightly knotted sludge particles are simply falling down through a turbid effluent. He will observe how much and what type of straggler floc, if any, remains in the supernatant liquor above the main sludge mass.

The importance of conscientious, perceptive observation during the first five minutes can not be over emphasized. During these first five minutes the operator will acquire additional insight into sludge character and quality, and will be in a much better position to evaluate what the settlometer test reveals.

The sixty-minute observation is the second most important in the time series. It provides a check on final clarifier sludge blanket characteristics and is used to compute process equilibrium indices and operational control adjustment requirements.

After the tests are completed, the settlometers should remain undisturbed for at least four hours. The time at which previously compacted sludge starts to swell and rise to the surface is another important indicator of sludge quality. Settled sludge should not remain down forever, any more than it should gasify and pop to the surface during the sixty-minute test cycle. Well-oxidized sludge will frequently begin to swell somewhat after ninety minutes and will usually float to the surface within two to four hours after the test was started.

A portion of the sample collected for the settlometer test should be saved for solids determinations.

CENTRIFUGE TESTS

The centrifuge permits rapid determination of mixed liquor and return sludge solids concentrations for immediate use in calculating solids distribution ratios, effective return sludge percentages, solids concentration rates, clarifier sludge detention times, and a host of other process relationships used to determine operational control demands.

The use of 12.5 ml API centrifuge tubes in a clinical centrifuge, with a six place horizontal head, revolving at approximately 2,000 rpm has been found convenient and appropriate for sewage plant control testing. The mixed liquor and return sludge specimens should be centrifuged for a standardized fifteen minute

interval to assure consistent compaction and to avoid discrepancies that can be introduced by slight variations in testing time when shorter intervals (say from one to three minutes) are used. Shorter time intervals may be used for "trim spins" and other special tests when great numbers of specimens are centrifuged to determine the solids balance in multiple aeration tanks or clarifiers.

The centrifuge is an exceedingly useful and convenient tool for searching out and correcting unbalanced sewage or return sludge flow distribution as well as unequal mixed liquor and return sludge solids concentrations in multiple tank plants. It has also been used effectively to determine return sludge percentages in the all too many cases where flow meters have been missing or were in error. Mixed liquor and return sludge concentration data frequently are plugged into the mixing formulae, described in Part III. It is then possible to determine either the primary effluent flow rate into the aeration tanks or the sludge withdrawal rate from the final clarifiers when either of the meters for these two locations is missing or inoperative.

Some operators question the use of the centrifuge for sludge concentration determination because such tests results can not always be correlated with suspended solids determinations

by the laboratory balance. The variation in the ratio of mixed liquor suspended solids concentration determined by the laboratory balance to that determined by the centrifuge is affected by sludge age and oxidation and is, therefore, one of the virtues of the centrifuge test; not a defect. Furthermore, the centrifuge test result, because it is influenced by the specific gravity and the surface area of the sludge mass, provides a realistic measure of effective sludge concentration.

EFFLUENT TURBIDITY TESTS

Two turbidity determinations should be made on the sample collected from the final clarifier. A photo-electric activated readout type turbidimeter with results expressed in Jackson turbidity units (JTU) is recommended. The turbidity of excellent final effluents usually ranges between 1.0 and 3.0 JTU. Final effluent turbidities greater than 3.0, and especially those exceeding 10.0 JTU, indicate that the full purification capability of the activated sludge process has not been achieved.

Upon delivery to the control station, the effluent should be stirred and used for the first turbidity test.

The final effluent sample should then be put aside for a one-hour settling period to permit gravity separation of

PROPER SAMPLING HANDLING
FOR TURBIDITY TEST

CENTRIFUGED
SLUDGE SAMPLES

TURBIDITY READING

extraneous floatable scums and settleable solids that may be attributed to flow overloads or inappropriate final clarifier features. At the end of this time interval, the turbidity of the subnatant liquor in the settled final effluent sample should be determined.

Special additional precautions should be observed while pouring the "settled" specimens into the turbidimeter test vial. The specimen container should be carefully lifted from the work bench and any accumulated surface scum should be poured to waste before the settled liquid (free from any sludge that may have settled to the bottom of the container) is poured into the test vial. The pouring operation must be gradual and continuous to avoid creating air bubbles and to eliminate surface scums or settled solids that might otherwise cause erroneous interpretation of the test results.

When performed properly, the turbidity test will reflect process performance. If the final effluent contains excessive suspended solids, for example, differences in the turbidity test results on settled versus unsettled effluent specimens will indicate whether the problem was created by improper process control, hydraulic overloads or by defective final clarifiers. In other words, if the final clarifiers lack scum baffles and skimmers or have inappropriately placed final effluent launders, or if

the tank geometry induces unnecessary velocity currents, the turbidity of the settled specimen will reveal the true effect of control adjustments on sludge characteristics and process equilibrium. Many times the final effluent produced by good sludge at proper process equilibrium contains unnecessarily high concentrations of solids that are needlessly forced out of the clarifiers by inappropriate or malfunctioning equipment. The object of this turbidity test is to define process response and control requirements rather than to document built-in, and usually not immediately correctable, plant defects.

Turbidimeter calibration and use should follow manufacturer's instructions.

DISSOLVED OXYGEN TESTS

At least once per day, and preferably once during each eight hour shift, dissolved oxygen concentrations should be determined at the inlet and at the outlet ends of each "pass" or compartmented area of the aeration tanks. Additional dissolved oxygen determinations should be made more frequently at "one" or "a single" aeration tank sampling station to reveal dissolved oxygen variations throughout each 24-hour cycle. These additional tests usually are run once every four hours and should be scheduled to include the intervals when influent loads increase in the early afternoon and decrease in the early morning hours.

A battery-operated dissolved oxygen probe is much more convenient and probably more accurate than the Winkler Method. The DO probe does require periodic calibration and maintenance to assure reliable operation and accurate results.

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